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Résume -
De nouveaux résultats préliminaires sur la photodesintégration du deuton réalisée avec LEGS sont présentés. Les activités expérimentales avec LADON sont rapidement passées en revue. Quelques indications sont données sur des activités possibles avec GRAAL.

Abstract - New preliminary results on the deuteron photodisintegration at LEGS are presented. The experimental activity at LADON is rapidly reviewed and some indication is given for the possible activity at GRAAL.

1 - Photon beams

Backward Compton scattering of laser light against the electrons of a storage ring was initiated at the Frascati National Laboratory in 1978 with the construction of the LADON beam on ADONE /1/. In its final arrangement, with the laser cavity stretched over the whole straight section, this beam could deliver polarized photons at the rate of 2E+05 with a maximum energy of 80 MeV /2/. The success of this technique sparked a second initiative at the Brookhaven National Laboratory /3/ where the first LEGS-photon beam was obtained in 1987. Here the same Argon-Ion Laser used at Frascati was shone against the 2.5 GeV electrons of the X-ray Machine of the National Synchrotron Light Source (NSLS) producing a polarized photon beam with a maximum energy of 300 MeV.The photons were tagged by detecting the scattered electrons in a magnetic spectrometer. In recent years also the LADON set-up has been upgraded with the introduction of a tagging system (TALADON /4/).
Finally the construction of a third beam like these, GRAAL in the Gev-region, has been recently approved by the Scientific Council of the European Synchrotron Radiation Facility (ESRF) in Grenoble and it is scheduled to be operating in 1994 /4/. The present running conditions for the LADON and LEGS-beams are summarized in Tab.I together with the characteristics that are expected for the GRAAL-beam.
The aim of the present paper is to rapidly review some of the physics that has been done at LADON, the present program at LEGS and to give some particular insight into the future activity at GRAAL.

TABLE I

Project name		Ladon°	Taladon+	Legs*	Graal**
Location		Frascati		Brookhaven	Grenoble
Energy defining method		collimation	internal tagging	external tagging	internal tagging
Electron energy GeV		1.5		2.5	6
Photon energy eV		2.45		3.53	3.53
Gamma energy MeV		5-80 variable	35-80 simultaneous	180-300	300-1500
Energy resolution FWHM	MeV	0.07-8	4-2	6	18
	%	1.4-10	5	2	1.2
Electron current A		0.1		0.2	0.1
Gamma intensity s^{-1}		$2 \cdot 10^5$	$5 \cdot 10^5$	$5 \cdot 10^6$	$5 \cdot 10^6$
Date of operation real or expected		1978	1989	1987	1995

° Laser **ADON**e, +**TA**gged **LADON**, * **L**aser **E**lectron **G**amma **S**ource, ** **GR**enoble **A**nneau **A**ccelerateur **L**aser.

2 - Physics at LADON

At Frascati a great deal of effort has been initially devoted to the photodisintegration of the deuteron. The differential cross section of this process with polarized photons can be written as

$$\frac{d\sigma}{d\Omega} = I_0(\theta) + P \cdot I_1(\theta) \cdot \cos 2\varphi \tag{1}$$

where P is the degree of linear polarization, θ is the c.m. scattering angle and φ is the angle between the electric vector of the incident photon and the scattering plane. The two structure functions I_1 and I_0 that contain the dynamics of the reaction represent the polarization-sensitive and insensitive parts of the cross section. The photon asymmetry defined by

$$\Sigma(\theta) = \frac{d\sigma^{\parallel} - d\sigma^{\perp}}{d\sigma^{\parallel} + d\sigma^{\perp}} = \frac{I_1(\theta)}{I_0(\theta)} \tag{2}$$

has been measured between 19.8 and 60.8 MeV over the angular range 15-165 degrees for the neutron in the CM-system /5/.

Asymmetry data at 60.8 MeV are shown in Fig.1. The dashed line has been obtained by Arenhövel and independently by Cambi et al. /6/ using the Reid soft-core (RSC) nucleon-nucleon potential and including meson exchange currents and isobaric contributions. No appreciable differences are predicted if the Hamada-Johnston or the Paris potentials are used. However, as the energy increases the differences become more noticeable, and the data at 60.8 MeV favour the older version B of the DeTourreil-Sprung (DTS-B) potential (solid line in Fig.1).

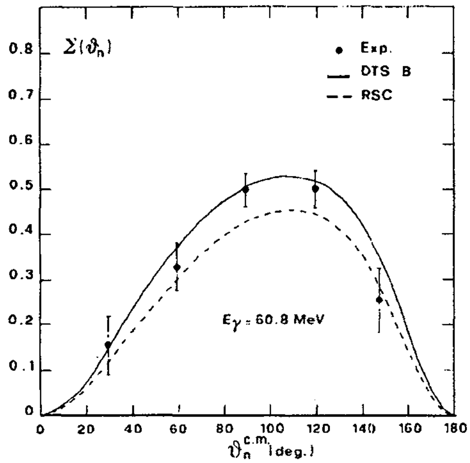

Fig. 1 - Azimuthal asymmetry as a function of c.m. neutron angle at Eγ=60.8 Mev.

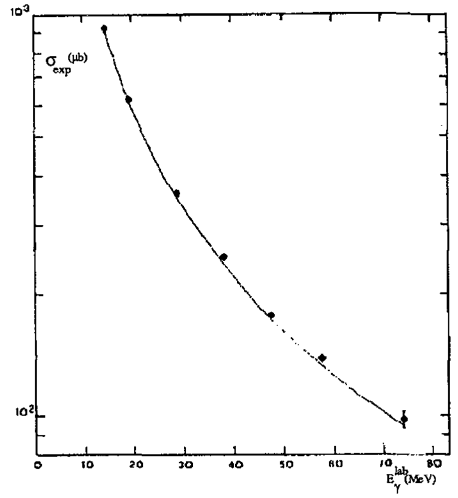

Fig. 2 - Total photodisintegration cross section.The solid line represents the theoretical calculation from A.Cambi et al. /6/.

This set of asymmetry measurements was later complemented with the measure of the total deuteron photodisintegration cross section in the photon energy range between 15 and 75 MeV /7/, is shown in Fig. 2 together with the theoretical predictions calculated by A.Cambi et al. /6/.

The absence of a striking qualitative or quantitative difference between theory and experiment confirms, within the obtained accuracy, the substantial validity of the standard theory at low energy and therefore does not support the claim for the need of further degrees of freedom in the description of the process as suggested by E. Hadjimichael and D.P. Saylor in Ref./8/.

The conclusion from these two experiments was that meson exchange currents and isobaric contributions were indeed essential at low energy but that effects involving quarks were either confined to the higher energy region or too small to be detected at low energy. Better sensitivity to the details of the nucleon-nucleon potential was left over to measurements at higher energy.

Another important result obtained at LADON was the measurement of the absolute total cross section for the ^{4}He(γ,p) ^{3}H reaction between 28.6 and 58.1 MeV /9/.

Results of this measurement are shown in Fig.3 together with the evaluation of Calarco et al. /10/ for the ^{4}He(γ,p) ^{3}H and ^{4}He(γ,n)^{3}He. The comparison of the LADON results with the most recent data on the ^{4}He(γ,n) ^{3}He total cross section provides a mean value for R= (γ,p)/(γ,n)= 1.01±.06 and therefore excludes the charge symmetry-breaking effect in ^{4}He implied by the Calarco's analysis of the data around 25 MeV. For an exhaustive review of the other LADON results in photo-fission studies and (γ,p), (γ,n) reactions see Ref /13/.

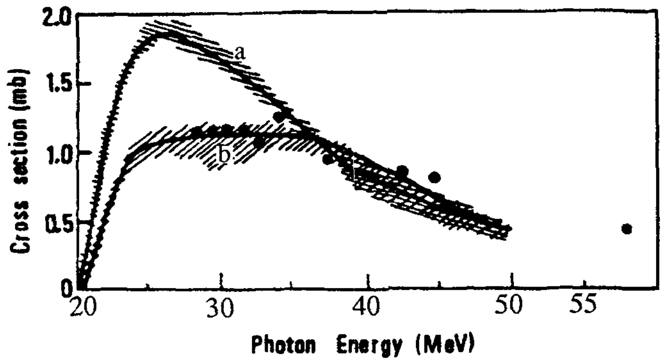

Fig. 3 - Total $^4He(\gamma,p)$ ^3H cross section.Solid lines are the J.R.Calarco et al. /10/ evaluation for the $^4He(\gamma,p)$ ^3H (curve a) and $^4He(\gamma,n)$ ^3He B(curve b); dashed areas take into account the experimental uncertainties. Solid points are from Ref. /9/

3 - Physics at LEGS

The LEGS-beam is presently running on a deuteron photodisintegration experiment with linearly polarized photons in the gamma energy region 175-300 MeV.

However the goal is also to extend these measurements down to at least 95 MeV to tie up with the LADON data. Since most of this low energy region lies outside the acceptance of the tagging system, the kinematics will only be determined by the proton angle and energy measurements. Very preliminary data on the photon asymmetry at 206 MeV are presented in Fig.4 together with the theoretical predictions calculated by Arenhövel with the Paris /11/ and Bonn /12/ potentials.

Figs 5,6 show the separated values for I_0 and I_1 compared with the most up-to-date experimental results from Bonn /14/ and Frascati /15/.

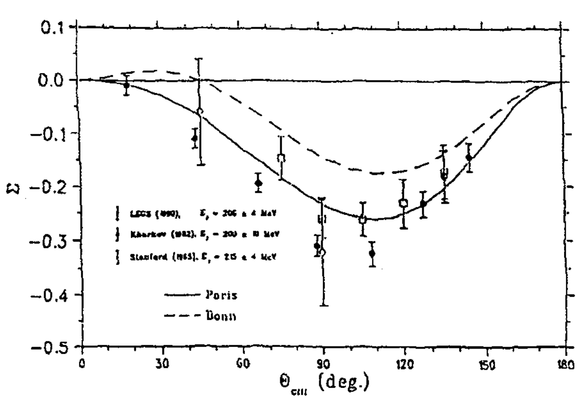

Fig. 4 - Photon polarization asymmetry as a function of c.m.proton angle at Eγ=206 Mev. Full circles-LEGS; open squares-Gorbenko et al./16/;open triangles-Liu /17/.Solid /11/ and dashed /12/ curves are theoretical calculations by Arenhövel using the Paris and Bonn potentials, respectively.

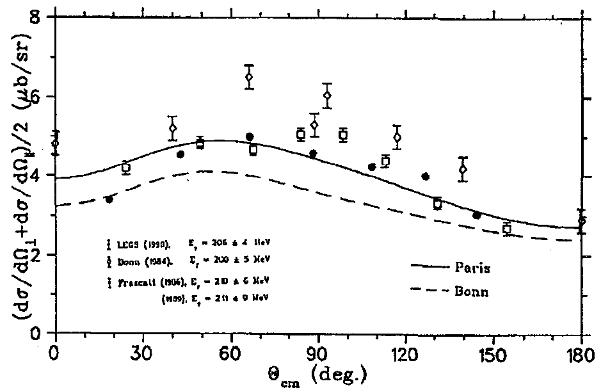

Fig. 5 - $I_0(\theta)$ at Eγ=206 Mev (full circles-LEGS;open squares-J.Arends et al. /14/; open triangles-E.De Sanctis et al. /15/. Curves as in Fig.4.

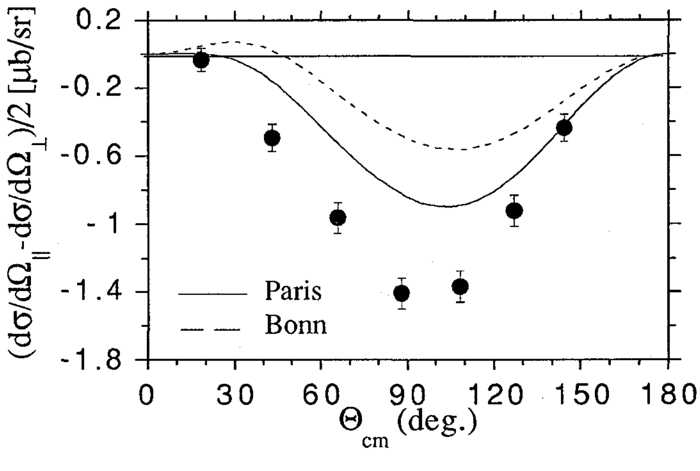

Fig. 6 - $I_1(\theta)$ at Eγ=206 Mev (full circles-LEGS).Curves as in Fig.4.

Since the most sensitive tests of any nuclear model come through comparisons with I_1 and there are no other direct measurements of this term, the main aim of the experiment is to give the absolute values for both I_0 and I_1. It is clear from Fig.4 and 6 that the polarization observables at these medium energies already show strong sensitivities to the nucleon-nucleon potential.

Besides testing nuclear models, photodisintegration with polarized photons may be a quite sensitive way of searching for dibaryons. Most dibaryons are predicted to be of high spin and thus their presence could show up most dramatically in I_1, which is the polarization dependent part of the cross section.

After the deuterium photodisintegration, the LEGS program will concentrate on two Compton scattering experiments on the nucleon, one in the region of the first resonance, which is sensitive to the E2/M1 mixing ratio in the excitation of the delta, and the other below pion threshold, which is sensitive to the nucleon electric and magnetic polarizabilities.

Reasonable theoretical estimates for the E2/M1 mixing ratio range from -0.9% to -2.9%. Almost all these models have as a consequence a non-vanishing d-state component in the nucleon wavefunction, which is loosely translated into the statement that the nucleon must be deformed. The signature for this would be an E2 component in the photo-excitation of the delta.

A variety of attempts have been made to reanalyze old data, and these have produced ratios ranging from +4% to -4% /18/. The errors in estimating the E2/M1 mixing ratio come partly from the fact that most of the data were collected in experiments that were not intended to determine this quantity, and partly from uncertainties in the effects of interfering non-resonant background processes. A better measurement is sorely needed and the use of polarized photons has the potential of removing most of these possible backgrounds.

Another problem in elastic photon scattering for which the availability of a polarized gamma-ray beam can produce a substantial improvement in understanding is the measurement of the nucleon polarizabilities. These are fundamental properties that contain valuable information on the quark structure of the nucleon. Although the electric polarizability of the proton probably dominates the magnetic, recent measurements have increased the range of possible values for these quantities. New measurements with polarized photons could lead to a significant reduction in the uncertainties. Current limits on the polarizabilities of the neutron are too uncertain to allow a meaningful comparison with theory.

This situation cannot be improved by scattering unpolarized photons, because of an inherent ambiguity between the electric and magnetic contributions in the case of the neutron. However, this ambiguity can be completely removed in scattering experiments with linearly polarized gamma rays.

Finally a resurgent interest in the pion's electric and magnetic polarizabilities has arisen from the consideration that chiral symmetry (and thereby QCD) makes an unambiguous prediction for the size of both parameters which is about three standard deviations from their experimentally measured values. It is clearly important to mount an experimental effort to remeasure these quantities since this is the only area at present where a firm chiral symmetry prediction appears to be violated experimentally.This measure could be initiated at LEGS during the data taking for the E2/M1 mixing ratio on the proton.

4 - Physics at GRAAL

As shown in Tab.I, the energies obtainable at GRAAL extend up to 1.5 Gev with the usual Argon-Ion laser used at LADON and LEGS and can be increased up to 1.8 Gev with the frequency quadrupled Nd-Yag laser proposed in /19/. Among the different experimental possibilities that this beam can open up I would like to spend few words on the possible use of circularly polarized photons together with polarized targets. Compton scattering of circular photons on spin 1/2 particles is higlhy sensitive to their polarization state and it has been used for many applications, from studies of spin distributions in ferro-magnetic materials to measurements of the electron polarization in storage rings /20/. There is no reason, in principle, why this argument could not be applicable to a system of fermions like quarks or partons in a polarized nucleon. As a matter of fact it can be shown that in the scaling region, where the parton picture has been firmly established,deep inelastic Compton scattering of circular photons on polarized nucleons can give informations on the parton spin distributions that are not equivalent to the ones obtainable with polarized electrons. Photons and electrons couple differently with the charges of the quarks and therefore the spin distributions for the same flavour are weighed differently in the two cases.

One the most significant result obtained recently by the EMC collaboration at CERN seems to indicate that these distributions violate the Ellis and Jaffe sum rule derived on solid ground within QCD and SU3-symmetry.This has generated a lot of speculations and triggered more experimental work.

Even if the scaling region has been approached at energies much higher than those available at GRAAL, precursor scaling effects appear to occur at unexpectedly low values of the momentum transfer (<3 Gev^2). Hence it would not be surprising that even at the GRAAL energies one could throw some new light into this problem by using circular photons instead of polarized leptons. Moreover, recent speculations /21/ have been raised on the fact that the Ellis and Jaffe sum rule, which amounts to a positive number in the scaling region,has to meet the Drell-Hearn-Gerasimov sum rule at Q^2=0 and this is a negative number. Therefore some dramatic turn-over effect has to take place in the intermediate region between these two extremes.Data from an old experiment at SLAC indicates that nothing seems to happen down to a Q^2 value of .5 Gev^2.Thus, it is in the region of very low Q^2 where one has to find the answer, unless something even deeper is underlaying all this. On the other hand we also know that this is the region where non-perturbative QCD (or higher-twist effect) plays a dominant but not fully understood role. Last but not least,measurements on the neutron would lead to a test of the Bjorken sum rule. A violation of this sum rule would imply that not only QCD is incorrect,but also current algebra! Experiments with circular photons at GRAAL are certainly limited in energy but can contribute significantly to clarify this extremely interesting phenomenology

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